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Karen A. Sanderson
(Typed or printed name of person mailing paper or fee)

Karen A. Sanderson
(Signature of person mailing paper or fee)

APPLICATION FOR UNITED STATES LETTERS PATENT

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

Be it known that Stephen Memory a citizen of the UNITED KINGDOM, residing at 1402 40th Avenue, Kenosha in the County of Kenosha and State of Wisconsin and C. James Rogers a citizen of CANADA, residing at 5133 S. Lakeshore Drive, Racine in the County of Racine and State of Wisconsin and Gregory G. Hughes a citizen of the UNITED STATES, residing at 4002 S. 75th Street, Milwaukee in the County of Milwaukee and State of Wisconsin and Frank M. Grippe a citizen of the UNITED STATES, residing at 1618 S. Beaumont Avenue, Kansasville in the County of Racine and State of Wisconsin and Rif Cheema a citizen of the UNITED STATES, residing at 1247 - 40th Avenue, Kenosha in the County of Kenosha and State of Wisconsin and William Markusen a citizen of the UNITED STATES, residing at 4916 Vrana Lane, Racine in the County of Racine and State of Wisconsin and Kenneth Ritt a citizen of the UNITED STATES, residing at 1845 Shoop Street, Racine in the County of Racine and State of Wisconsin have invented a new and useful SPLIT FIN FOR A HEAT EXCHANGER

SPLIT FIN FOR A HEAT EXCHANGER

FIELD OF THE INVENTION

This invention relates to a split fin construction for use in heat exchangers, and more particularly, for a heat exchanger having a plurality of rows of tube runs from front to back and wherein it is desirable to minimize heat transfer through the fin from one row of tubes to another.

BACKGROUND OF THE INVENTION

There are a variety of applications wherein it is important to limit heat conduction between the front and rear side of a heat exchanger. Such applications are typified by those wherein the fluid temperature entering the heat exchanger is at a significantly different level than the temperature of the fluid exiting the heat exchanger. One such application is in a refrigeration system heat exchanger such as a condenser, or more specifically, a gas cooler and a refrigeration system utilizing a transcritical refrigerant. CO_2 is an example of such a refrigerant.

Another application occurs where two or more heat exchanger cores, each receiving a separate fluid, are located in series in the flow path for another heat exchange fluid such as a gas as air. An example of such an application would be one usually found in a vehicular context wherein, for example, the core of a condenser or gas cooler for an air conditioning system is located upstream or downstream of a core for engine coolant.

In the former case, in order to decrease the refrigerant exit temperature as much as possible, it is desired to limit the conduction path across the depth of the heat exchanger such that the relatively much hotter entering refrigerant dissipates its heat to the coolant passing through the heat exchanger rather than to the exiting refrigerant via conduction through fins extending from front to back in the heat exchanger. In the latter case, it is desirable that heat from the radiator and the engine coolant therein is not conveyed to the condenser via common fins to impede the efficiency of operation of the condenser or vice versa.

In a typical gas cooled heat exchanger, cross conduction paths may exist both in the metal tubes as well as the metal fins. To avoid the formation of a cross conduction path in the metal tubes, the tubes in adjacent rows from front to back of the heat exchanger are spaced from one another. To minimize cross conduction through the fins, heat interrupters, typically in the form of slots, are located in the fins in alignment with the spaces between the rows of tubes in the heat exchanger. Examples of the latter are shown, for example, in Shinmura 5,000,257 and its reissue patent Re. 35,710; Sugimoto 5,992,514; Watanabe 5,720,341 and Yamanaka 6,000,460.

In each of the foregoing patents, a slot is formed wherein material is removed from the fin to form the slot which provides an interruption in the heat conduction through the fin. While these constructions are believed to be operative for their intended purpose, the fact that material is removed from the fin reduces the surface area of the

fin. As is apparent from Fourier's law, a reduction in area reduces heat transfer and thus the slots proposed by the above patentees, while providing the desired reduction in heat conduction through the fin from one side of the heat exchanger to the other, also increase gas side thermal resistance, reducing the efficiency of heat exchange from the fluid contained within the tubes to a gas which passes through the fins. As, in typical gas/fluid heat exchangers, gas side thermal resistance can account for as much as 95% of the total resistance to heat exchange from the gas to the fluid flowing within the tubes, it is highly desirable that reduction of heat conduction through the fin from one side of the heat exchanger to the other not be accompanied by an increase in gas side thermal resistance.

The present invention is directed to achieving that desire.

SUMMARY OF THE INVENTION

It is a principal object of the invention to provide a new and improved gas side fin for use in heat exchangers having plural rows of tube runs from front to back of the heat exchanger. More specifically, it is an object of the invention to provide such a fin wherein heat conduction through the fin from one side of the heat exchanger to the other is minimized while at the same time is not accompanied by an increase in gas side thermal resistance.

An exemplary embodiment of the invention accomplishes the foregoing in a heat exchanger having a front and a back with a plurality of spaced rows of flattened tubes from front to back which define aligned tube runs in each row. Serpentine fins are abutted to adjacent tube runs

in each row and extend from front to back so that each fin is common to each of the rows. The serpentine fins have heat flow interrupters in each fin at a location in the space between the aligned tube runs in each row. The invention contemplates the improvement wherein the heat flow interrupter is defined by a slit extending completely through the fin and which is characterized by the absence of the removal of any material of which the fin is made at the slit.

In a preferred embodiment, the edges of the slit are displaced from the remainder of the fin.

In one embodiment, the edges of the slit extend at an acute angle to the remainder of the fin.

Even more preferably, the edges of each slit are displaced in opposite directions from the remainder of the fin at the acute angle.

In another embodiment of the invention, the edges of each slit are displaced into offset, spaced planes.

In still another embodiment of the invention, the slits in each fin defining the heat flow interrupters in each fin are separated by short joining sections and the edges of each slit are spaced from one another by deforming the joining sections.

Preferably, the joining sections are made thinner than the remainder of the fins. By way of example only, a coining operation may be utilized on the joining sections to make them thinner thereby displacing the edges of the slit into spaced relation.

In a preferred embodiment, the aligned ones of the tube runs are connected in hydraulic series so as to be useable as a gas cooler or a gas cooler/evaporator in a refrigeration system or in a heat pump system.

Other objects and advantages will become apparent from the following specification taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a somewhat schematic perspective view of a heat exchanger made according to the invention;

Fig. 2 is an enlarged, fragmentary sectional view taken approximately along the line 2-2 in Fig. 1;

Fig. 3 is a fragmentary sectional view taken approximately along the line 3-3 in Fig. 2;

Fig. 4 is a fragmentary sectional view taken approximately along the line 4-4 in Fig. 2 and showing a modified embodiment of the invention;

Fig. 5 is a fragmentary sectional view taken approximately along the line 5-5 in Fig. 2 and showing still another modified embodiment of the invention;

Fig. 6 is a view similar to that taken along the line 5-5 in Fig. 2 but showing still a further modified embodiment; and

Fig. 7 is a schematic of a refrigeration system, specifically a heat pump system, in which a heat exchanger having a fin made according to the invention may be employed.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The following description will describe the invention generally in the terms of a refrigeration system which is intended to encompass heat pump systems as well. The context of the description will be that of a vehicular heating/cooling system but it is to be specifically understood that the invention is not limited to use in vehicular systems. The invention will also be described in the context of a gas cooler wherein a gas, typically air, is utilized to cool and/or condense a single fluid such as a refrigerant; and the term "gas cooler" is intended to include both condensers and coolers which cool refrigerant without condensing it. However, the invention is also applicable to heat exchangers having a plurality of cores, each receiving a different working fluid as, for example, a plural core heat exchanger for cooling both the refrigerant from a gas cooler and the coolant for an engine or the like. Similarly, while the invention will be described in the context of a gas, typically air, cooling another working fluid within the heat exchanger, it should be appreciated that the heat exchanger can be employed wherein the gas is heated by the working fluid as well. In short, the invention is not to be limited by the following description except in so far as stated in the appended claims.

Referring to Fig. 1, a heat exchanger made according to the invention is illustrated and is seen to include a pair of spaced, parallel, tubular headers 10,12. Of course, header plates fitted with tanks could be employed in lieu of the tubular headers 10,12 if desired.

In the illustrated embodiment, the header 10 is provided with an outlet schematically illustrated at 14 while the header 12 is provided

with an inlet, schematically indicated at 16. A direction of air flow through the heat exchanger is illustrated by an arrow 18 and it will be seen that the just described arrangement of the inlet 16 and outlet 14 provide a counter/cross flow heat exchange regime. However, in some instances the air flow direction 18 can be reversed.

When the heat exchanger is intended to be used as a gas cooler or gas cooler/evaporator in a refrigeration system, the foregoing counter/cross flow arrangement is preferred. That is also true of the use of tubular headers 10,12 because of their high pressure resistance.

A plurality of flattened tubes 20 extend between the headers 10,12 that are in fluid communication with the interior of each. Each flattened tube is configured in a serpentine configuration so as to have three runs 22, 24 and 26 which are parallel with each other and which are aligned with each other from the front 28 of the heat exchanger to the rear 30 thereof. Consequently, the runs 22 form a front row of runs within the heat exchanger, the runs 24 form an intermediate row of runs within the heat exchanger and the runs 26 form a rear row of runs within the heat exchanger. The runs 22, 24 and 26 are spaced by a small gap 27 (Fig. 2) so as to prevent or otherwise minimize heat conduction between the runs 22, 24 and 26 as would result if they were in contact with one another.

The various runs are connected by arcuate sections 32. In the usual case, the arcuate sections 32 will be approximately in line with one or the other of the headers 10,12 in the direction of air flow 18 through the heat exchanger. Preferably, the tubes making up the runs

22,24,26 and the arcuate sections 32 are flattened tubes having a major dimension D_M and a minor dimension D_m transverse thereto. Desirably, to maximize the cross sectional area of the gas flow path through the heat exchanger, the runs 22,24,26 are oriented so that the major dimension D_M is parallel to the direction of air flow 18 through the heat exchanger.

At the same time, in high pressure applications, such as gas coolers used in transcritical refrigeration systems, it is desirable that the diameter of the headers 10,12, be as small as possible. Thus, it is conceivable, and even likely that the tube major dimension D_M will be greater than the diameter of either of the headers 10 or 12. In such a case, the ends of the runs 22,26, shown collectively at 34, are received in elongated slots 36 in the respective headers 10,12 which extend in the direction of elongation of the respective header 10,12. To achieve this relation along with the relation requiring the tube major dimensions D_M to be parallel to the direction of air flow 18, immediately adjacent to the ends 34, the tubes are provided with a twist 38, typically, but not always, 90°. Similar twists are also provided at the ends of each arcuate section 32 and are schematically illustrated by dotted lines 40. The twists 40 facilitate bending of the tubes to include the arcuate sections 32.

Serpentine fins, generally designated 42, are disposed between adjacent ones of the tubes with each fin 42 extending between an aligned pair of the runs 22, the runs 24 and the runs 26 from the front 28 to the back 30 of the heat exchanger. Alternatively plate or other fins may be used. Thus, there exists a heat conductive flow path between the runs 22, 24 and 26 through the fins 42.

As generally alluded to previously, it is undesirable in many applications that such a heat conduction path exists. As mentioned previously, those applications include ones where a sizable temperature differential exists between the runs 22 and 26 as would be the case in a gas cooler or gas cooler/evaporator when being operated as a gas cooler in a transcritical refrigeration system. Another typical example would be where certain of the runs are being employed in a condenser for a refrigerant and others of the runs are being employed as a radiator for coolant such as engine coolant. In the case of the latter, of course, additional headers to separate the refrigerant stream from the coolant stream would be employed. As seen in Fig. 1, each of the fins 42 includes a plurality of generally flat sections 44, which are connected to each other by crests 46, which, in turn, are metallurgically bonded as by brazing, soldering or welding, to the flat side of each of the tube runs 22,24,26 between which the fin 42 is located.

As seen in Fig. 2, each section 44 is defined by three segments including a first segment 48 extending between the tube runs 22, a second segment 50 extending between the tube runs 24 and a third segment 52 extending between the tube runs 26. Each of the segments 48,50,52 is typically provided with louvers 54 which may be of conventional construction.

Between each of the segments 48,50,52 is a flow interrupter. Two such flow interrupters are shown in Fig. 2 which are made according to different embodiments of the invention. A first flow interrupter is generally designated 56 while a second is generally designated 58. According

to the invention, each flow interrupter is defined by an elongated slit that runs continuously through each fin 44 and is positioned to be located in alignment with the spaces 27 between the runs 22, 24 and 26. The slits are illustrated at 62 in Fig. 2 and each is interrupted by connecting sections 64 that may be a few millimeters in length and which are positioned at intervals in the corresponding slit 62. The connecting sections 64 need not be present at each section 44 of each fin 42 and typically will not be. They only need be provided with such frequency as to maintain the integrity of a fin 42 so that it will not separate into individual parts at each slit 62.

The slits 62 are generally straight line and have opposed edges. As illustrated in Fig. 3, the opposed edges are shown at 66 and 68, face one another and are generally transverse to the direction of air flow 18. In the embodiment of the invention illustrated in Fig. 3, the edges 66 and 68 are virtually in abutment, but not quite in abutment, with each other, and, because of the interruption in the continuity of the fin 42 at this location, interrupt the flow of heat from one segment 48,50,52 to the other. It is to be particularly noted that the slits 62 are formed without the removal of any material from the fin 42 itself. As a consequence, the surface area of each fin 42 is not diminished in any way by the presence of the slits 62 and as a consequence, each fin 42 has a maximum surface area for heat exchange of air flowing in the direction 18. Consequently, the greater surface area of each fin that results provides improved heat transfer.

In the embodiment shown in Fig. 3, it is desirable, though not absolutely necessary, that if braze material is employed, that braze material be located on the side walls 70 of the tube runs 22,24,26 as opposed to being on the fin 42. This assures that the slit 62 will remain continuous after it is formed as a result of the prevention of flow of brazed metal into the slit 62 that might braze the edges 66,68 together.

The embodiment of Fig. 4 provides further assurance that there will be no brazing together of the edges 66,68 of each slit 62. In this embodiment, the segments 50 of each fin 42 which extend between the tube runs 24 are displaced in the direction of elongation of the tube runs 22,24,26 from segments 48,52 without the removal of any material from the fin 42. As a result, gaps 70 in a plane generally transverse to the plane of each segment 48,50,52 are provided to define the flow interrupters 56.

Still another alternative is illustrated in Fig. 5. In the embodiment of Fig. 5, one of the flow interrupters 58 is illustrated. One edge 72 of the slit 62 is bent upwardly while another edge 74 is bent downwardly so that the two edges 72,74 are spaced as illustrated in Fig. 5. Again, a gap between the edges 72,74, is formed as in the embodiment of Fig. 4 as well, and again, without the removal of any material from the fin 42 which would reduce its surface area.

Fig. 6 illustrates still another embodiment of the invention. In this embodiment, the joining sections 64 are compressed by a suitable operation as, for example, by coining. This results in the edges of the slits 72,74 being driven away from one another even though occupying the

same plane so as to form a gap 76 between adjacent ones of the segments 48,50,52. Since the coining operation does not cause removal of any material from the fin, fin surface area is again maximized to improve heat transfer.

Fig. 7 illustrates a preferred environment of use of heat exchanger made according to the invention. Specifically illustrated is a refrigeration system as may be used for refrigeration or air conditioning purposes, and more specifically, a heat pump system which may be employed for both heating and cooling. Two heat exchangers, generally designated 80 and 82, respectively, and made according to the invention are employed as gas cooler/evaporators with one acting as a gas cooler when the other is acting as an evaporator, and vice versa. The two are connected in a conventional heat pump circuit with valves 84 as is a conventional compressor 86 and an expansion valve 88. Typically a suction line heat exchanger (not shown) will be located on the inlet side 90 of the compressor 86 along with an accumulator (also not shown).

When the system in Fig. 7 is employed for cooling purposes, the heat exchanger 80 will be acting as a gas cooler and will receive compressed refrigerant from the outlet side 92 of the compressor 86 via the heat pump connected plumbing and valves 84 on a line 94. The compressed, hot refrigerant will exit the heat exchanger 80, now acting as a gas cooler on a line 96 to ultimately be passed through the expansion valve 88 which discharges on a line 98 connected to the heat exchanger 82. The refrigerant will be expanded in the heat exchanger 82, now acting as an evaporator, and ultimately returned to the inlet side 90 of the

compressor 86 via the previously mentioned suction line heat exchanger, if present. Conventional fans 100 are employed to drive air through both of the heat exchangers 80,82.

When the system of Fig. 7 is employed for heating purposes, the heat exchanger 82 will be employed as a gas cooler and the heat exchanger 80 as an evaporator. In this case, hot compressed refrigerant from the outlet side 92 of the compressor 86 will be provided to the heat exchanger 82 on the line 98 to exit therefrom on a line 102 which will be connected by the heat pump connected plumbing and valves 84 to the expansion valve 88. From the expansion valve 88, the refrigerant will enter the heat exchanger 80 on the line 94 and expand therein as the heat exchanger 80 will be acting as an evaporator at this time. The refrigerant exiting the heat exchanger 80 will exit on the line 96 to be returned via the heat pump connected plumbing and valves 84 to the inlet side 90 of the compressor 86.

From the foregoing, it will be appreciated that a heat exchanger made according to the invention is ideally suited for those applications where heat conduction through fins common to several rows of runs of tubing is highly undesirable. The provision of the slits 62 in the fins 54 between the segments 48, 50 and 52 to act as heat interrupters achieves that function without the removal of any of the material of which the fins 42 are made. Consequently, the fins 42 retain their original surface area which then is available for heat transfer, making the fins 42 more efficient that those fins heretofore known which involve the removal of material from the fins to provide the heat interrupters.

The invention is not only applicable to those heat exchangers wherein a large temperature differential from one run to the next is encountered where all of the runs contain a single working fluid such as a refrigerant, but may be used with efficacy in combination heat exchangers such as common core condensers and radiators wherein the fins are common to both the condensing section and the radiator section.

The heat interrupters 56,58 are easily fabricated during the typical roll forming operation used to provide the serpentine fins 42 which provides a simple and economical way to accomplish the desired result without the necessity of removing material from the fins 52 and disposing of the scrap constituted by such removed material.

Finally, it will be appreciated that in some instances, the principles of the invention are not limited to serpentine fin heat exchangers but may be employed in plate fin heat exchangers as well.